Formerly Utilized Sites Remedial
Action Program (FUSRAP)

Maywood Chemical Company Superfund Site

ADMINISTRATIVE RECORD

Document Number

MISS- 112.

US Army Corps
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117690
M-710

Argonne National Laboratory
9700 South Cass Avenue, Argonne, Illinois 60439

DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE MAYWOOD SITE

by

D.E. Dunning
Environmental Assessment Division

May 1994

work sponsored by

U.S. Department of Energy
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DERIVATION OF URANIUM RESIDUAL RADIOACTIVE MATERIAL GUIDELINES FOR THE MAYWOOD SITE

by D.E. Dunning

SUMMARY

Residual radioactive material guidelines for uranium were derived for the Maywood site located in the Boroughs of Maywood and Lodi and the Township of Rochelle Park, New Jersey. The Maywood site became contaminated as a result of thorium-processing operations conducted at the former Maywood Chemical Works (MCW) facility from the early 1900s through 1959. Properties within the Maywood site include the Maywood Interim Storage Site (MISS); the Stepan Company (formerly MCW) property; and numerous residential, commercial, federal, state, and municipal properties that became contaminated as a result of the former thorium-processing operations. Several vicinity properties have been remediated by previous removal actions. The U.S. Department of Energy (DOE) is responsible for cleanup activities at the Maywood site under its Formerly Utilized Sites Remedial Action Program (FUSRAP), as defined in the Federal Facilities Agreement (FFA) between DOE and the U.S. Environmental Protection Agency (EPA) for the site. Remedial actions at the Maywood site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. In addition, DOE has chosen to integrate the values of the National Environmental Policy Act (NEPA). The DOE is currently preparing a comprehensive remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) for remedial action at the Maywood site.

Uranium guidelines were derived on the basis of the requirement that the 50-year committed effective dose equivalent to a hypothetical individual who lives or works in the immediate vicinity of the Maywood site should not exceed 100 mrem/yr following decontamination. The DOE residual radioactive material guideline computer code, RESRAD, which implements the methodology described in the DOE manual for implementing residual radioactive material guidelines, was used in this evaluation. Four potential scenarios were considered for the site; the scenarios vary with regard to time spent at the site, sources of water used, and sources of food consumed. The results of the evaluation indicate that the basic dose limit of 100 mrem/yr will not be exceeded for uranium (including uranium-234, uranium-235, and uranium-238) within 1,000 years, provided that the soil concentration of combined uranium (uranium-234, uranium-235, and uranium-238) at the Maywood site does not exceed the following levels: 3,800 pCi/g for Scenario A (industrial worker); 8,300 pCi/g for Scenario B (recreationist); 1,400 pCi/g for Scenario C (resident using a water source not affected by site conditions as the only water source); and 910 pCi/g for Scenario D (resident farmer using well water as the only water source). The uranium guidelines derived in this report apply to the combined activity concentration of uranium-234, uranium-235, and uranium-238, and were calculated on the basis of a dose limit of 100 mrem/yr. In setting the final uranium guidelines for the Maywood site, DOE will apply the as low as reasonably achievable (ALARA) policy to the decision-making process, along with other factors, such as whether a particular scenario is reasonable and appropriate and whether the contamination is isolated and localized.

1 INTRODUCTION AND BRIEF HISTORY

The Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 by the U.S. Atomic Energy Commission (AEC), a predecessor of the U.S. Department of Energy (DOE). The mandate of the program is to identify, evaluate, and, if necessary, decontaminate sites previously used by the AEC or its predecessor, the Manhattan Engineer District (MED), or otherwise designated for FUSRAP responsibility.

The Maywood site is located in Bergen County, New Jersey. The U.S. Congress assigned DOE the responsibility of cleaning up the contamination at the Maywood site that resulted from past thorium-processing operations at the Maywood Chemical Works (MCW) from the early 1900s through 1959. Remedial actions at the Maywood site are being conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). In addition, DOE has chosen to integrate the values of the National Environmental Policy Act (NEPA), which ensure that the environmental consequences of a proposed action are considered as part of the decision-making process for that action. The DOE is currently preparing a comprehensive remedial investigation/feasibility study-environmental impact statement (RI/FS-EIS) for remedial action at the Maywood site. This report presents guidelines for residual uranium concentrations in soils at the Maywood site. The guidelines were derived with the RESRAD computer code (Gilbert et al. 1989; Yu et al. 1993) on the basis of a dose limit of 100 mrem/yr.

1.1 SITE DESCRIPTION AND SETTING

The Maywood site is composed of properties in the Boroughs of Maywood and Lodi and the Township of Rochelle Park, New Jersey. The three municipalities adjoin each other and are located in a highly developed area of northeastern New Jersey, approximately 20 km (12 mi) north-northwest of New York City and 21 km (13 mi) northeast of Newark, New Jersey (Figure 1). The Maywood site became contaminated, at least in part, as a result of thorium processing and disposal activities that took place during the operation of the former MCW facility from the early 1900s through 1959. The Maywood site consists of the Maywood Interim Storage Site (MISS); the Stepan Company property (formerly the MCW); and numerous residential, commercial, federal, state, and municipal properties in Maywood, Rochelle Park, and Lodi, New Jersey. These properties became radioactively contaminated as a result of thorium-processing operations at the MCW. The site is listed on the National Priorities List (NPL) as the Maywood Chemical Company.

The U.S. Congress has assigned DOE the responsibility of cleaning up contamination at the site that resulted from thorium-processing operations by the former MCW. The U.S. Environmental Protection Agency (EPA) oversees the Maywood site cleanup. Each agency's responsibilities are described in a Federal Facilities Agreement (FFA) negotiated by

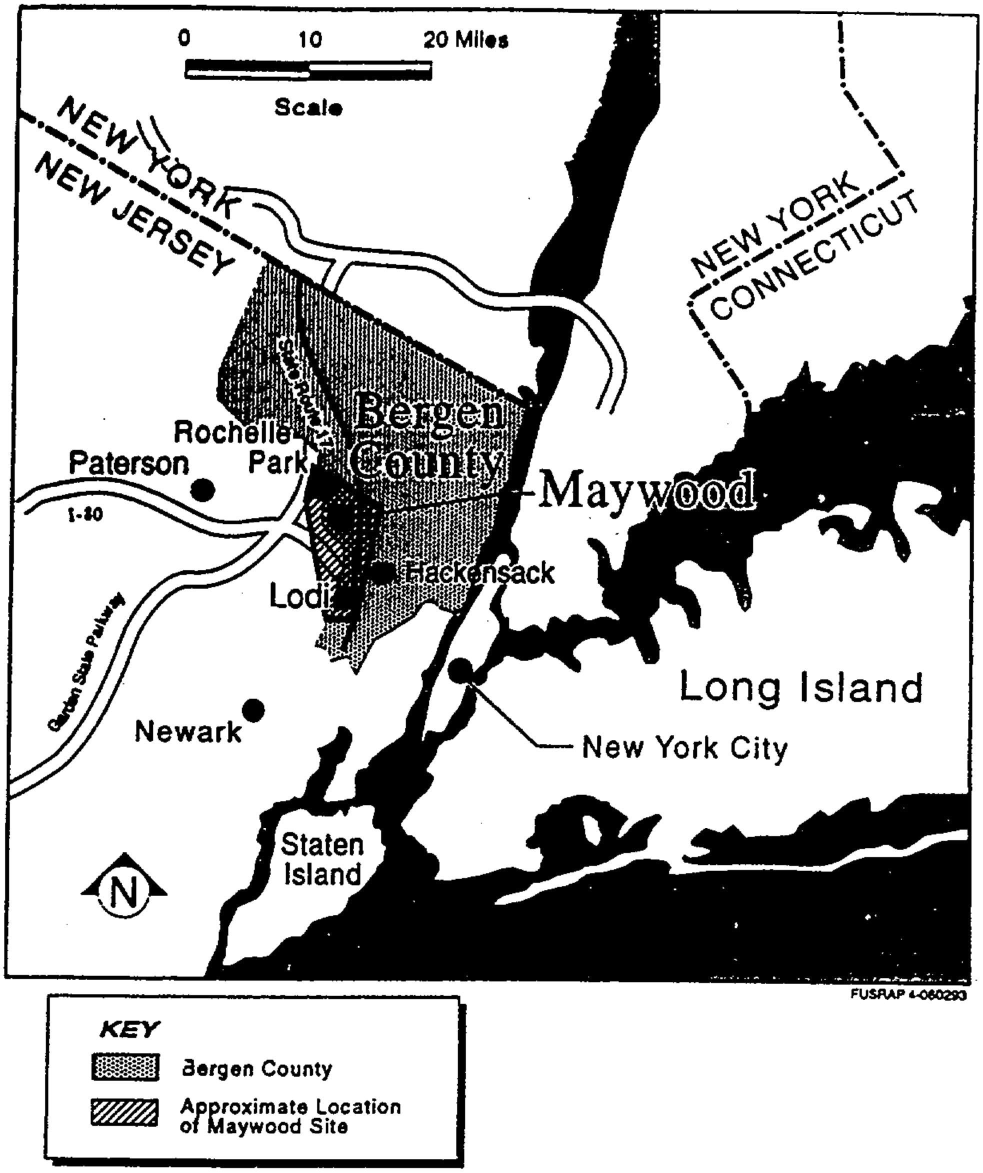

FIGURE 1 Location of the Maywood Site

DOE and EPA Region II. The DOE is primarily responsible for addressing radioactive contamination and the contaminants that meet the definition of FUSRAP waste as set forth in the FFA. A separate RI/FS is being conducted by the Stepan Company, owner of the former MCW property, and focuses on chemical contamination at the site under an administrative order of consent (1987) and an administrative order (1991). Although DOE and Stepan Company RI/FS activities are being conducted independently, EPA oversight over both actions, in consultation with the parties, will ensure that sufficient coordination occurs between the parties to fully address the Maywood site.

For the purpose of developing and evaluating remedial action alternatives, the Maywood site has been divided into multiple operable units (OUs) on the basis of land use and environmental media of concern. The location of the properties composing these OUs is shown in Figure 2. Each OU is briefly described below.

The MISS is a 4.7-ha (11.7-acre) property owned by DOE and located in the Borough of Maywood and the Township of Rochelle Park. The MISS property was previously part of a 12-ha (30-acre) property owned by the Stepan Company and formerly part of the MCW; DOE acquired the property from the Stepan Company in 1985. The property contains an interim waste storage pile, two buildings (Building 76 and a pumphouse), two partially buried structures, temporary office trailers, a reservoir, and two rail spurs. The property is bordered on the west by State Route 17; on the north by a New York, Susquehanna, and Western Railroad line; and on the south and east by commercial and industrial properties. Residential properties are located north of the railroad line and within 274 m (300 yd) to the north of the MISS property boundary. The interim storage pile at the MISS occupies approximately 0.8 ha (2 acres) and contains about 27,000 m^3 (35,000 yd^3) of contaminated soils and materials from previous removal actions conducted on vicinity properties at the Maywood site. A building at the MISS (Building 76) houses containerized solid waste from previous removal actions and site investigations. Former waste retention ponds are also located at the MISS. The property is enclosed by a chain-link fence, and access is restricted within the fenced area. Major features of the MISS property are indicated in Figure 3.

The Stepan Company, a pharmaceutical manufacturer, is located at 100 West Hunter Avenue in the Borough of Maywood, adjacent to the MISS. The property covers 7.4 ha (18 acres), approximately two-thirds of which contains buildings, some in or near locations where the MCW thorium-processing operations occurred. Burial pits containing thorium-processing and other wastes are located on the site (see Figure 3). The property (excluding the main office and parking area) is enclosed by a chain-link fence, and access is restricted within the fenced area.

Residential vicinity properties in the Boroughs of Maywood and Lodi and the Township of Rochelle Park contain radioactive contamination from thorium-processing operations. These properties were identified by DOE through surveys performed by Oak Ridge National Laboratory (ORNL). Nine residential properties in Rochelle Park on Grove Avenue and Park Way and eight residential properties in Maywood on Davison Avenue and Latham Street were completely decontaminated by DOE between 1984 and 1986 and independently verified for use without restriction. Eight residential properties in Lodi have also been decontaminated and have been independently verified as clean; one additional property in Lodi was partially remediated during previous removal actions. Of the remaining 32 contaminated residential properties to be addressed by DOE, 30 are located in Lodi and two are located in Maywood.

Commercial/government vicinity properties include 27 properties located in Maywood, Rochelle Park, and Lodi. Twenty commercial vicinity properties are part of the Maywood site. State and federally owned properties include right-of-ways for Interstate 80, a State

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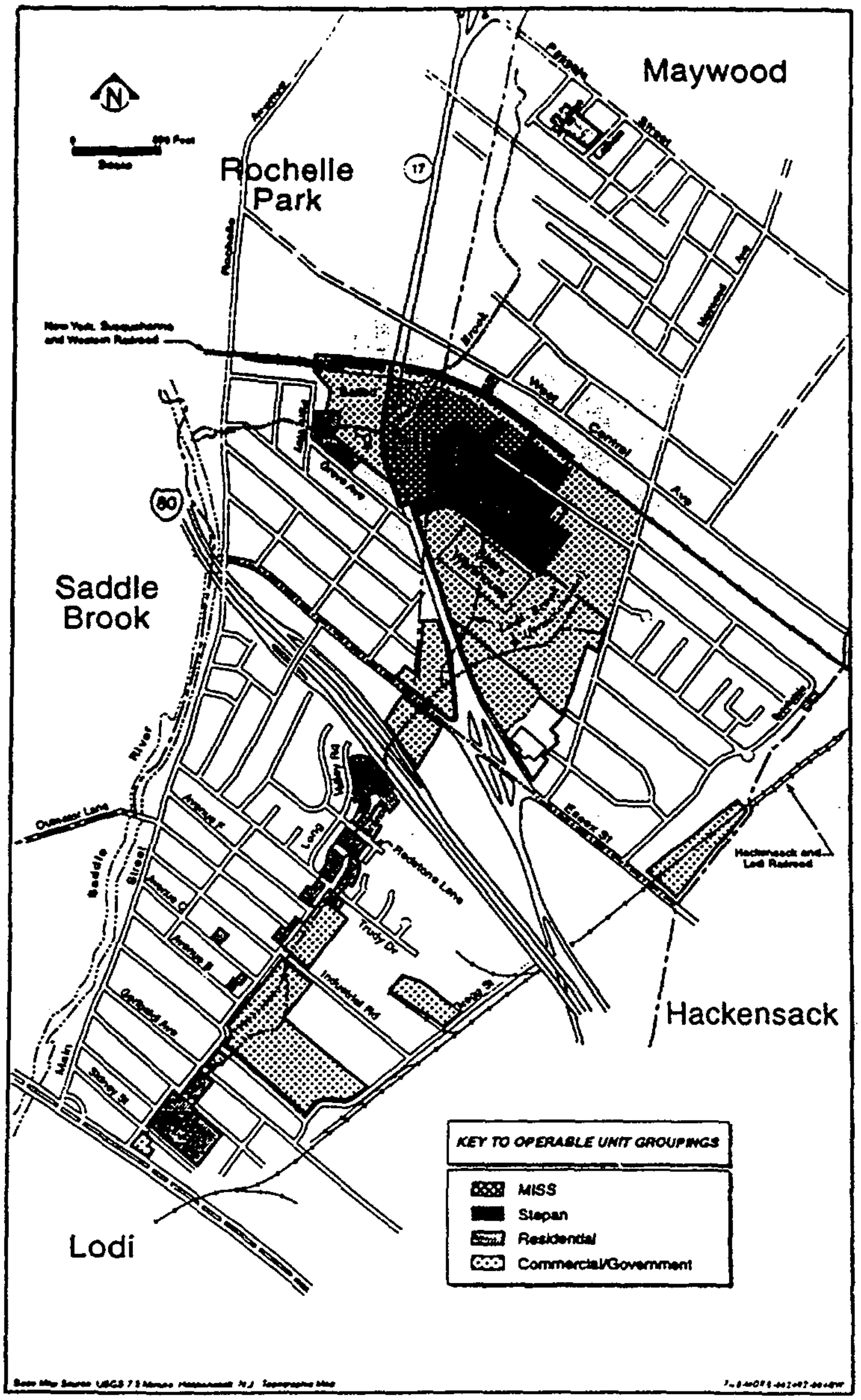

FIGURE 2 Map of the Maywood Site Showing the Locations of the Maywood Interim Storage Site and Vicinity Properties

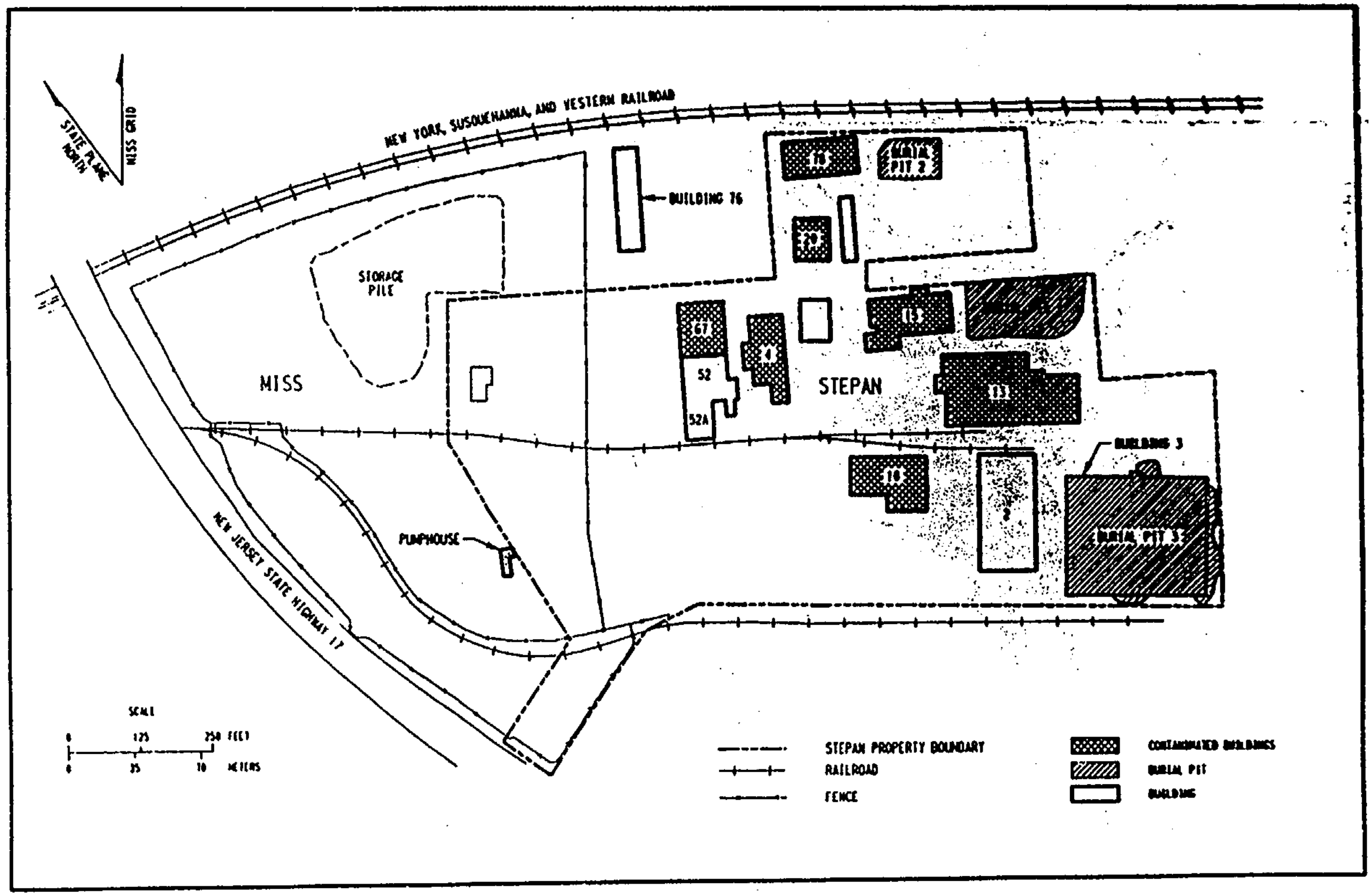

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FIGURE 3 Site Map of the Maywood Interim Storage Site and Adjacent Stepan Company Property

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Route 17 embankment, and the New Jersey Vehicle Inspection Station. Four municipal properties (three parks and a fire station), residential streets suspected to have contaminated soils below the surface, and contaminated sediments from Lodi Brook are also included in this OU. The majority of these properties were contaminated through the same processes as the residential properties — transport of contaminated sediments along former stream channels or use of contaminated material as fill and mulch. Three of these properties (Ballod, Sears, and State Route 17) were once part of the former MCW property and were used, at least in part, for waste disposal. A portion of one property (Ballod) was remediated during a previous removal action.

Contaminated buildings and structures are located on the MISS and Stepan properties only. As indicated in Figure 3, radiologically contaminated buildings include the pumphouse at the MISS and the guardhouse and Buildings 4, 10, 13, 15, 20, 67, and 78 on the Stepan property. The radiological contamination is generally localized in discrete areas within buildings and is fixed in place on building floors and surfaces and not readily transferable (i.e., removable by incidental contact). The pumphouse is no longer in use; however, the contaminated buildings at Stepan are part of an active industrial complex. The contaminated buildings are all old buildings that existed during the time that the MCW was processing thorium. No buildings on vicinity properties were found to be contaminated other than one residence in Lodi that contained contaminated building materials from the MCW; the contaminated portion of the structure has been removed and reconstructed.

The regional climate at the Maywood site is humid, with a normal annual precipitation of about 107 cm (42.3 in.). Mean monthly temperatures range from 0.4°C (31°F) in January to 24.9°C (76.8°F) in July. The prevailing winds are from the northwest during October through April and from the southwest during the remainder of the year.

The Maywood site lies within the Saddle River drainage basin. A small portion of the site is located within the 100-year floodplain of the Saddle River. Westerly Brook flows under the MISS property and State Route 17 through a concrete culvert and eventually discharges into the Saddle River approximately 0.8 km (0.5 mi) to the west. Another perennial stream on the Maywood site, Lodi Brook, originates as two branches on the Sears property; most of the original stream channel has been replaced by a subsurface storm drain system, but the former channel correlates with the distribution of contaminated materials in the Borough of Lodi. Lodi Brook empties into the Saddle River downstream of Westerly Brook's confluence with the river. Depth-to-groundwater is shallow and ranges from approximately 1 to 4.6 m (3 to 15 ft) below ground surface.

1.2 SITE HISTORY

The MCW was constructed in 1895. In 1916, the plant began extracting thorium and rare earths from monazite sands for use in manufacturing industrial products such as mantles for gas lanterns. The plant also produced a variety of other materials, including lithium compounds, detergents, alkaloids, and oils. The plant stopped accepting monazite sands for extraction in 1956 but processed stockpiled materials until 1959. On the basis of available historical information and knowledge of the chemical processes involved, the chemicals identified as having been used in the thorium extraction process include sulfuric acid, nitric acid, ammonium hydroxide, and ammonium oxalate. Oxalic acid was also used at the site in the production of higher-grade thorium.

The waste was generated from the extraction process in slurry form. Until 1932, the slurry was pumped to two earthen-diked areas west of the plant. At that time, the disposal areas were affected by the construction of State Route 17, which separated the diked areas from the plant and partially buried them. Waste retention ponds also existed throughout the area of the MCW that is now the MISS.

Some of the process wastes were removed for use as mulch and fill on nearby properties, thereby contaminating those properties with radioactive materials. Although the fill consisted primarily of tea and coca leaves from other MCW processes, these materials were apparently contaminated with the thorium-processing wastes. Additional wastes migrated off the property via natural drainage associated with the former Lodi Brook. Most of the open stream channel in Lodi has been replaced by a subsurface storm drain system.

The MCW received a radioactive materials license from the AEC in 1954. The MCW sold the site to the Stepan Company in 1959, which received a license from the AEC in 1961. Although the Stepan Company never processed radioactive materials, the company agreed to take certain corrective measures in the former disposal area on the west side of State Route 17 (now known as the Ballod property). The Stepan Company began to clean up residual thorium-processing wastes in 1963. From 1966 through 1968, Stepan removed residues and tailings from the Ballod property and reburied them on the Stepan property in three burial pits (Figure 3). After these actions were completed, the AEC certified the portion of the property west of State Route 17 for use without radiological restrictions in 1968.

Radioactive contamination, however, was discovered in the northeast corner of the property in 1980 after a private citizen reported radioactive contamination near State Route 17 to the New Jersey Department of Environmental Protection (NJDEP). A survey of the area (State Route 17, Ballod property, and Stepan property) conducted by the NJDEP identified the contaminants as thorium-232 and radium-226. The U.S. Nuclear Regulatory Commission (NRC) was notified of the results and undertook additional surveys from November 1980 to January 1981; these surveys confirmed high concentrations of thorium-232 in soil samples collected from both the Stepan and Ballod properties. Accordingly, the NRC requested a comprehensive survey of the area.

In January 1981, the EG&G Energy Measurements Group conducted an aerial radiological survey of the Stepan property and surrounding properties. The survey, which covered a 10-km^2 (3.9-mi^2) area, indicated contamination not only on the Stepan and Ballod properties but also in areas to the north and south of the Ballod property. During February 1981, ORNL performed a separate radiological ground survey of the Ballod property, the results of which eventually led to its designation for remedial action under FUSRAP. In June 1981, an additional radiological survey of the Stepan and Ballod properties commissioned by the Stepan Company produced similar findings.

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By enacting a provision of the Energy and Water Development Appropriations Act of 1984, Congress authorized DOE to undertake a decontamination research and development project at the Maywood site. Accordingly, the site was assigned to FUSRAP, and DOE negotiated access to a 4.7-ha (11.7-acre) portion of the Stepan Company property for use as an interim storage facility for contaminated materials that were to be removed from vicinity properties. This area is now known as the MISS. In September 1985, ownership of the MISS was transferred to DOE.

In late 1983, DOE initiated a program of surveys of properties in the vicinity of the former MCW plant. From 1984 to 1986, DOE conducted removal actions on 25 properties and placed the waste in temporary storage on the MISS. The interim waste storage pile contains about 27,000 m^3 (35,000 yd^3) of contaminated soil and debris removed from these vicinity properties; the interim storage pile occupies approximately 0.8 ha (2 acres) with an average height of 5.5 m (18 ft). The DOE has maintained a comprehensive environmental monitoring program at the MISS since 1984.

A time-critical removal action was conducted in July 1991 to decontaminate a residential property at 90 Avenue C in Lodi, in response to radiological surveys that identified interior gamma exposure rates above DOE guidelines within a portion of the building. The original owner of the residence was an employee of the MCW, who apparently used discarded building and fill materials from the MCW to construct an addition to the house. Contaminated soil and building materials generated during this removal action were packaged in appropriate containers and placed in Building 76 at the MISS for interim storage.

Eighty-five properties, including the Stepan property and the MISS, have (or have had) residual contamination resulting from MCW thorium-processing activities and are included as a part of the Maywood site. The properties include 56 residential properties (25 of which have been previously remediated and 1 partially remediated), 3 properties owned by the state or federal government, 4 municipal properties, and 20 commercial properties (1 of which has been partially remediated). Vicinity properties are believed to have been contaminated by the use of the waste materials as mulch and fill or through sediment transport via Lodi Brook.

The Maywood site was placed on the National Priorities List (NPL) by the EPA on September 8, 1983. All remedial actions at the site conducted by DOE are being coordinated with EPA Region II under CERCLA. The limits of DOE's responsibilities for the Maywood site are defined under a negotiated FFA between DOE and EPA Region II that became effective April 22, 1991.

Implementation of comprehensive remedial actions will be preceded by completion of the RI/FS-EIS process for the site (Argonne National Laboratory/Bechtel National, Inc. [ANL/BNI] 1992). It is DOE's policy (DOE 1989) to integrate the values of NEPA with the procedural and documentation requirements of CERCLA at sites for which it has responsibility. The combined RI/FS-EIS process will conclude in the issuance of a record of decision (ROD) that will identify the selected remedy for the Maywood site.

1.3 DERIVATION OF CLEANUP GUIDELINES

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Because no generic cleanup guidelines for uranium applicable to remedial actions at FUSRAP sites are available, uranium guidelines are derived on a site-specific basis. The purpose of this report is to present the derivation of the residual radioactive material guidelines for uranium (i.e., uranium-234, uranium-235, and uranium-238) that are applicable to remedial action at the Maywood site; that is, the residual concentration of uranium in a homogeneously contaminated area that must not be exceeded if the site is to be released for use without radiological restrictions. On the assumption that the uranium is the only radionuclide present at an above-background concentration, the derivation of site-specific uranium guidelines for the Maywood site was based on the dose limit of 100 mrem/yr (DOE 1990). The RESRAD computer code, which implements the methodology described in the DOE manual for implementing residual radioactive material guidelines (Gilbert et al. 1989; Yu et al. 1993), was used to derive these guidelines. The DOE will establish the final uranium guidelines for the Maywood site by applying the as low as reasonably achievable (ALARA) policy to the derived guidelines presented in this report, along with other factors, such as whether a particular scenario is reasonable and appropriate and whether the contamination is isolated and localized.

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2 SCENARIO DEFINITIONS

Current land use at properties composing the Maywood site ranges from residential to commercial/industrial to recreational. Four potential exposure scenarios were considered in deriving site-specific uranium guidelines, including each of these land use categories. In all scenarios it is assumed that, at some time within 1,000 years, the site will be released for use without radiological restrictions following decontamination.

Scenario A assumes industrial use of the site; this is considered the most likely future scenario at the MISS, the Stepan Company property, and numerous commercial/industrial properties within the Maywood site. A hypothetical employee is assumed to work in the area of the site for 8 hours per day (7 hours indoors and 1 hour outdoors), 5 days per week, 50 weeks per year. The industrial worker does not ingest drinking water, plant foods, or fish from the decontaminated area, or ingest meat or milk from livestock raised in the decontaminated area.

Scenario B assumes recreational use of the site; for example, it is assumed that, at some time in the future, the site will be used as a public park; this is considered the expected scenario for the three municipal parks included within the Maywood site. A hypothetical person is assumed to spend 15 hours per week, 50 weeks per year in the decontaminated area of the park. The recreational user does not ingest drinking water, plant foods, or fish from the decontaminated area, or ingest meat or milk from livestock raised in the decontaminated area.

Scenario C assumes residential use of the site; the Maywood site includes numerous residential properties, and continued residential land use is expected. All water used by the resident is assumed to come from a distant source not affected by site conditions (e.g., a municipal water supply); the site is currently served by a municipal water supply, and there is no known use of groundwater at the site as a drinking water source. The resident ingests produce grown in a garden in the decontaminated area but does not ingest meat or milk from livestock raised in the decontaminated area nor fish grown in the decontaminated area.

Scenario D assumes the presence of a resident farmer at the site who drinks water obtained from a well located at the downgradient edge of the decontaminated area, ingests produce grown in a garden in the decontaminated area, ingests meat and milk from livestock raised in the decontaminated area, and ingests fish taken from a pond that is assumed to be constructed adjacent to and downgradient of the decontaminated area. All water used for drinking, irrigation, and livestock is assumed to be drawn from the on-site well. There is no current agricultural activity at the site, and production of livestock or construction of a fishing pond in the decontaminated area are considered extremely unlikely.

Potential radiation doses resulting from nine exposure pathways were analyzed: (1) direct exposure to external radiation from the decontaminated soil material; (2) internal radiation from inhalation of contaminated dust; (3) internal radiation from inhalation of emanating radon-222; (4) internal radiation from incidental ingestion of soil; (5) internal

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radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from a well located at the downgradient edge of the decontaminated area; (6) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from the on-site well; (7) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and irrigated with water drawn from the on-site well; (8) internal radiation from ingestion of fish from a pond downgradient from the decontaminated area; and (9) internal radiation from drinking water drawn from the on-site well.

The RESRAD computer code, version 5.01 (Yu et al. 1993), was used to calculate the potential radiation doses to each of the hypothetical future receptors on the basis of the following assumptions:

- The resident spends 5,900 hours per year on-site in the decontaminated area (16.5 hours/day indoors and 0.5 hour/day outdoors for 350 days/year). The industrial worker spends 2,000 hours per year on-site (7 hours/day indoors and 1 hour/day outdoors for 250 days/year). The recreationist spends 750 hours per year on-site, all outdoors. The resident farmer spends 4,380 hours per year indoors, 2,190 hours outdoors in the decontaminated area, and 2,190 hours away from the site. Exposure times for the resident and employee were selected for consistency with the baseline risk assessment for the site (DOE 1993).
- For all scenarios, the contaminated zone is taken to be the MISS property.
- After remedial action, no cover material is placed over the decontaminated area.
- The walls, floor, and foundation of the house or commercial building reduce external exposure by 20%, and the indoor dust level is 40% of the outdoor dust level.
- The depth of the house or building foundation is 1 m (3 ft) below ground surface, with an effective radon diffusion coefficient of 2×10^{-8} m^2/s.
- Under Scenario D, a well located at the downgradient edge of the decontaminated area is assumed to provide 100% of the drinking water consumed by the resident farmer and is also used for irrigating vegetables in the on-site garden and fodder for livestock. Under Scenarios A, B, and C, all water is assumed to come from a distant source unaffected by site conditions.
- Under Scenarios C and D, the resident or resident farmer is assumed to consume produce grown in a garden in the decontaminated area. The industrial worker and recreationist do not consume produce from an on-site garden.

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- Under Scenario D, the resident farmer is assumed to obtain meat and milk from livestock raised (i.e., foraged) in the decontaminated area. The industrial worker, recreationist, and resident do not consume meat or milk from livestock raised in the decontaminated area.

- An adjacent pond is assumed to provide 50% of the aquatic food (fish) consumed by the resident farmer (Scenario D). The industrial worker, recreationist, and resident do not consume fish from the decontaminated area.

- Hydrogeologic properties of the Maywood site were taken from the remedial investigation report (DOE 1992b), baseline risk assessment (DOE 1993), and FS-EIS (DOE 1994) for the site.

Most exposure parameter values were selected for consistency with values used in the baseline risk assessment (DOE 1993) and FS-EIS (DOE 1994); however, some additional exposure pathways that were determined in the baseline risk assessment to be implausible and/or inappropriate for the Maywood site (e.g., ingestion of meat and milk from livestock raised on-site) are considered here for completeness. Table 1 provides a summary of the exposure pathways considered for Scenarios A, B, C, and D. RESRAD input parameter values used in the analysis are tabulated in the Appendix.

TABLE 1 Summary of Pathways for Scenarios A, B, C, and D at the Maywood Site[a]

Pathway	Scenario A	Scenario B	Scenario C	Scenario D
External exposure	Yes	Yes	Yes	Yes
Particulate inhalation	Yes	Yes	Yes	Yes
Radon inhalation	Yes	Yes	Yes	Yes
Ingestion of soil	Yes	Yes	Yes	Yes
Ingestion of produce	No	No	Yes	Yes
Ingestion of meat from on-site livestock	No	No	No	Yes
Ingestion of milk from on-site livestock	No	No	No	Yes
Ingestion of fish from an on-site pond	No	No	No	Yes
Ingestion of water from an on-site well[b]	No	No	No	Yes

[a] Scenario A, industrial worker; Scenario B, recreationist; Scenario C, resident using a distant water source unaffected by site conditions; Scenario D, resident farmer using an on-site well as the only water source.

[b] Source of water used: 100% well water for drinking, irrigation, and livestock for Scenario D; 100% distant source for all purposes for Scenarios A, B, and C.

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3 DOSE/SOURCE CONCENTRATION RATIOS

The RESRAD computer code, version 5.01 (Yu et al. 1993), was used to calculate the dose/source ratio $DSR_{ip}(t)$ for uranium isotope i and pathway p at time t after decontamination. The time frame considered in this analysis was 1,000 years. Radioactive decay and ingrowth were considered in deriving the dose/source concentration ratios. The various parameters used in the RESRAD code for this analysis are listed in the Appendix. The calculated maximum dose/source concentration ratios for all pathways are presented in Tables 2 through 5 for Scenarios A, B, C, and D, respectively. For Scenarios A, B, and C, the maximum dose/source concentration ratios are predicted to occur at time zero (immediately after decontamination). For Scenario D, the maximum dose/source concentration ratio for uranium isotopes is estimated to occur approximately 1,000 years following decontamination. The primary exposure pathway for Scenarios A and B is predicted to be inhalation of resuspended particulates for uranium-234 and external exposure for uranium-235 and uranium-238. For Scenario C, the primary pathway is predicted to be ingestion of produce from an on-site garden for uranium-234 and external exposure for uranium-235 and uranium-238. For Scenario D, the primary pathway is predicted to be ingestion of groundwater for uranium-234 and uranium-238 and external exposure for uranium-235.

The summation of $DSR_{ip}(t)$ for all pathways p is the $DSR_i(t)$ for the ith isotope, that is,

$$DSR_i(t) = \sum_p DSR_{ip}(t) \quad .$$

The total dose/source concentration ratio for total uranium (enriched, depleted, or normal) can be calculated as

$$DSR(t) = \sum_i W_i \, DSR_i(t) \quad ,$$

where W_i is the existing activity concentration fraction at the site for uranium-234, uranium-235, and uranium-238. For this analysis, W_i is assumed to represent the natural activity concentration ratios of 1/2.046, 1/2.046, and 0.046/2.046 for uranium-238, uranium-234, and uranium-235, respectively. The total dose/source concentration ratios for single uranium isotopes and total uranium are provided in Table 6. These ratios were used to determine the allowable residual radioactivity for uranium at the Maywood site.

Uncertainty in the derivation of dose/source concentration ratios arises from the distribution of possible input parameter values as well as uncertainty in the conceptual model used to represent the site. Depending on the scenario, different parameters more strongly influence the results in each case. For Scenarios A, B, and C, the particulate inhalation, external exposure, and produce ingestion (Scenario C only) pathways contribute most of the dose, so uncertainty in parameters affecting these pathways (e.g., occupancy factors, thickness of the contaminated zone, shielding provided by buildings and site features, mass

TABLE 2 Maximum Dose/Source Concentration Ratios for Scenario A (industrial worker) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	2.6×10^{-4}	1.7×10^{-1}	2.5×10^{-2}
Particulate inhalation	9.3×10^{-3}	8.6×10^{-3}	8.6×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	3.6×10^{-4}	3.4×10^{-4}	3.4×10^{-4}
Ingestion of produce from on-site garden	0	0	0
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

[a] Maximum dose/source concentration ratios are predicted to occur at time zero (immediately following decontamination); all values are reported to two significant figures.

TABLE 3 Maximum Dose/Source Concentration Ratios for Scenario B (recreationist) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	1.2×10^{-4}	7.8×10^{-2}	1.1×10^{-2}
Particulate inhalation	4.1×10^{-3}	3.7×10^{-3}	3.7×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	7.8×10^{-4}	7.5×10^{-4}	7.5×10^{-4}
Ingestion of produce from on-site garden	0	0	0
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

[a] Maximum dose/source concentration ratios are predicted to occur at time zero (immediately following decontamination); all values are reported to two significant figures.

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TABLE 4 Maximum Dose/Source Concentration Ratios for Scenario C (resident) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	7.4×10^{-4}	4.9×10^{-1}	7.0×10^{-2}
Particulate inhalation	7.9×10^{-3}	7.3×10^{-3}	7.3×10^{-3}
Radon inhalation	0	0	0
Ingestion of soil	2.5×10^{-3}	2.5×10^{-3}	2.5×10^{-3}
Ingestion of produce from on-site garden	1.8×10^{-2}	1.8×10^{-2}	1.8×10^{-2}
Ingestion of meat from on-site livestock	0	0	0
Ingestion of milk from on-site livestock	0	0	0
Ingestion of fish from on-site pond	0	0	0
Ingestion of water from on-site well	0	0	0

[a] **Maximum dose/source concentration ratios are predicted to occur at time zero (immediately following decontamination); all values are reported to two significant figures.**

TABLE 5 Maximum Dose/Source Concentration Ratios for Scenario D (resident farmer) at the Maywood Site

Pathway	Maximum Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]		
	Uranium-234	Uranium-235	Uranium-238
External exposure	1.3×10^{-2}	3.3×10^{-1}	4.3×10^{-2}
Particulate inhalation	6.6×10^{-3}	1.7×10^{-2}	6.0×10^{-3}
Radon inhalation	1.8×10^{-3}	0	1.6×10^{-6}
Ingestion of soil	2.2×10^{-3}	7.9×10^{-3}	2.0×10^{-3}
Ingestion of produce from on-site garden	1.4×10^{-2}	6.9×10^{-2}	9.9×10^{-3}
Ingestion of meat from on-site livestock	2.9×10^{-3}	6.2×10^{-2}	2.1×10^{-3}
Ingestion of milk from on-site livestock	6.2×10^{-3}	5.7×10^{-3}	5.4×10^{-3}
Ingestion of fish from on-site pond	1.5×10^{-3}	1.5×10^{-3}	1.5×10^{-3}
Ingestion of water from on-site well	4.6×10^{-2}	4.7×10^{-2}	4.5×10^{-2}

[a] Maximum dose/source concentration ratios are predicted to occur approximately 1,000 years following decontamination (based on total uranium); all values are reported to two significant figures.

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TABLE 6 Total Dose/Source Concentration Ratios for Uranium at the Maywood Site

Radionuclide	Total Dose/Source Concentration Ratio (mrem/yr)/(pCi/g)[a]			
	Scenario A	Scenario B	Scenario C	Scenario D
Uranium-234	9.9×10^{-3}	5.0×10^{-3}	2.9×10^{-2}	9.4×10^{-2}
Uranium-235	1.8×10^{-1}	8.3×10^{-2}	5.2×10^{-1}	5.2×10^{-1}
Uranium-238	3.4×10^{-2}	1.6×10^{-2}	9.7×10^{-2}	1.1×10^{-1}
Total uranium	2.6×10^{-2}	1.2×10^{-2}	7.3×10^{-2}	1.1×10^{-1}

[a] All values are reported to two significant figures.

loading of contaminated airborne particulates, inhalation rate, and produce ingestion rate) have the greatest impact on model predictions, and parameters related to other pathways have relatively little impact. Because the maximum dose occurs at time zero for these scenarios, uncertainties in parameters related to the leaching of radionuclides from the contaminated zone do not affect the results. However, the opposite is true for Scenario D, in which a large fraction of the total dose is contributed by the drinking water pathway; in this case, the predicted dose is very sensitive to uncertainties in soil properties, meteorological parameters, distribution coefficients, water consumption rates, thickness of the contaminated zone, and other parameters related to the leaching and transport of radionuclides.

For the purposes of this analysis, site-specific parameter values, primarily from the RI/FS-EIS documentation for the Maywood site, have been used when available. RESRAD default values have been used when no site-specific data were available. These default values are based on national average or reasonable maximum values. The contaminated zone thickness of 2 m used to derive the dose/source concentration ratios is based on the assumption that the soil is uniformly contaminated to that depth; in reality, following decontamination of the site, the residual contamination would occur in localized areas and primarily in the near-surface soil and would not be dispersed uniformly throughout the site to this depth. Therefore, the calculated dose/source ratios are conservative. Furthermore, some of the exposure pathways evaluated in this analysis have been included for purposes of completeness, but are considered very unlikely. For example, the production of meat and milk from livestock raised on-site is considered very unlikely given the location and physical characteristics of the site. Similarly, development of a fishing pond at the site is not likely, given the physical and hydrogeologic characteristics of the site, surrounding land use, and the availability of other fishing resources in the area.

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4 RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

The residual radioactive material guideline is the concentration of residual radioactive material that can remain in a decontaminated area and still allow use of the area without radiological restrictions. Given the DOE radiation dose limit of 100 mrem/yr effective dose equivalent to a member of the public (DOE 1990, 1992a), the residual radioactive material guideline, G, for uranium at the Maywood site can be calculated as

$$G = DL \,/\, DSR \,,$$

where DL is the applicable radiation dose limit (100 mrem/yr) and DSR is the total dose/source concentration ratio listed in Table 6. The calculated residual radioactive material guidelines for individual uranium isotopes (uranium-234, uranium-235, and uranium-238) and total uranium are presented in Table 7.

In the calculation of the total uranium guidelines, it was assumed that the activity concentration ratio of uranium-238, uranium-234, and uranium-235 is 1:1:0.046. The derived guidelines for total uranium are 3,800 pCi/g for Scenario A, 8,300 pCi/g for Scenario B, 1,400 pCi/g for Scenario C, and 910 pCi/g for Scenario D. If uranium-238 is measured as the indicator radionuclide, then the uranium-238 limits for total uranium can be calculated by dividing the total uranium guidelines by 2.046. The resulting limits are 1,900 pCi/g, 4,100 pCi/g, 680 pCi/g, and 440 pCi/g for Scenarios A, B, C, and D, respectively.

In implementing the derived radionuclide guidelines for decontamination of a site, the law of the sum of fractions applies. That is, the summation of the fractions of radionuclide concentrations S_i remaining on-site, averaged over an area of 100 m^2 (120 yd^2) and a depth of 15 cm (6 in.) and divided by its guideline, G_i , should not be greater than unity:

$$\sum_i S_i \,/G_i \leq 1 \quad .$$

The derived guidelines are for a large, homogeneously contaminated area. For an isolated, small area of contamination (i.e., a hot spot), the allowable concentration that can remain on-site may be higher than the homogeneous guideline, depending on the size of the area of contamination and in accordance with Table 8.

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TABLE 7 Residual Radioactive Material Guidelines for Uranium at the Maywood Site

Radionuclide	Guideline (pCi/g)[a] Scenario A	Scenario B	Scenario C	Scenario D
Uranium-234	1.0×10^4	2.0×10^4	3.4×10^3	1.1×10^3
Uranium-235	5.5×10^2	1.2×10^3	1.9×10^2	1.8×10^2
Uranium-238	3.0×10^3	6.4×10^3	1.0×10^3	8.8×10^2
Total uranium	3.8×10^3	8.3×10^3	1.4×10^3	9.1×10^2

[a] All values are reported to two significant figures.

TABLE 8 Ranges for Hot Spot Multiplication Factors

Range	Factor (multiple of authorized limit)
$< 1\ m^2$	10[a]
$1 - <3\ m^2$	6
$3 - <10\ m^2$	3
$10 - 25\ m^2$	2

[a] Areas less than $1\ m^2$ are to be averaged over a $1\text{-}m^2$ area, and that average shall not exceed 10 times the authorized limit.

Source: Gilbert et al. (1989).

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APPENDIX:

PARAMETERS USED IN THE ANALYSIS OF THE MAYWOOD SITE

The parametric values used in the RESRAD code for the analysis of the Maywood site are listed in Table A.1. Some parameters are specific to the Maywood site; other values are generic.

TABLE A.1 Parameters Used in the RESRAD Code for the Analysis of the Maywood Site

		Value			
Parameter	Unit	Scenario A	Scenario B	Scenario C	Scenario D
Area of contaminated zone[a,b]	m^2	47,000	47,000	47,000	47,000
Thickness of contaminated zone[b]	m	2	2	2	2
Length parallel to aquifer flow[b]	m	220	220	220	220
Cover depth[b]	m	0	0	0	0
Density of contaminated zone[b]	g/cm^3	1.6	1.6	1.6	1.6
Contaminated zone erosion rate[b]	m/yr	0.0006	0.0006	0.0006	0.0006
Contaminated zone total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Contaminated zone effective porosity[a]	-[c]	0.26	0.26	0.26	0.26
Contaminated zone hydraulic conductivity[a]	m/yr	1.23	1.23	1.23	1.23
Contaminated zone b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Evapotranspiration coefficient[a]	-[c]	0.46	0.46	0.46	0.46
Precipitation[a]	m/yr	1.07	1.07	1.07	1.07
Irrigation[b]	m/yr	0.2	0.2	0.2	0.2
Irrigation mode[b]	-[c]	not used	not used	not used	overhead
Runoff coefficient[a]	-[c]	0.25	0.25	0.25	0.25
Watershed area for pond[a]	m^2	not used	not used	not used	55,750
Density of saturated zone[b]	g/cm^3	1.6	1.6	1.6	1.6
Saturated zone total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Saturated zone effective porosity[a]	-[c]	0.26	0.26	0.26	0.26
Saturated zone hydraulic conductivity[a]	m/yr	123	123	123	123
Saturated zone hydraulic gradient[a]	-[c]	0.01	0.01	0.01	0.01
Saturated zone b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Water table drop rate[b]	m/yr	0.0006	0.0006	0.0006	0.0006
Well pump intake depth[b] (below water table)	m	not used	not used	not used	10
Model: nondispersion (ND) or mass-balance (MB)[b]	-[c]	not used	not used	not used	ND
Well pumping rate[b]	m^3/yr	not used	not used	not used	250
Number of unsaturated zone strata[b]	-[c]	1	1	1	1
Unsaturated zone 1 thickness[a]	m	1	1	1	1
Unsaturated zone 1 soil density[a]	g/cm^3	1.6	1.6	1.6	1.6
Unsaturated zone 1 total porosity[a]	-[c]	0.45	0.45	0.45	0.45
Unsaturated zone 1 effective porosity[a]	-[c]	0.26	0.26	0.26	0.26

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TABLE A.1 (Cont.)

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Unsaturated zone 1 soil b parameter[a]	-[c]	5.3	5.3	5.3	5.3
Unsaturated zone 1 hydraulic conductivity[a]	m/yr	1.23	1.23	1.23	1.23
Distribution coefficient (all zones)					
Uranium-238[d]	cm^3/g	250	250	250	250
Uranium-235[d]	cm^3/g	250	250	250	250
Uranium-234[d]	cm^3/g	250	250	250	250
Protactinium-231[d,e]	cm^3/g	2500	2500	2500	2500
Thorium-230[d,e]	cm^3/g	60,000	60,000	60,000	60,000
Actinium-227[d,e]	cm^3/g	1500	1500	1500	1500
Radium-226[d,e]	cm^3/g	450	450	450	450
Lead-210[d,e]	cm^3/g	900	900	900	900
Inhalation rate[f]	m^3/yr	21,900	12,264	7300	7300
Mass loading for inhalation[f,g]	g/m^3	0.00003	0.00003	0.00003	0.00003
Indoor occupancy time fraction[f]	-[c]	0.20	0	0.65	0.65
Outdoor occupancy time fraction[f]	-[c]	0.03	0.086	0.02	0.02
Shielding factor from external radiation afforded by indoor occupancy[b]	-[c]	0.8	not used	0.8	0.8
Fraction of outdoor dust present indoors[b]	-[c]	0.4	not used	0.4	0.4
Shape factor, external gamma[b]	-[c]	1	1	1	1
Dilution length for airborne dust inhalation[b]	m	3	3	3	3
Soil ingestion rate[f]	g/yr	12.5	35	35	35
Homegrown fruit, vegetable, and grain consumption[f]	kg/yr	not used	not used	24	24
Homegrown leafy vegetable consumption[f]	kg/yr	not used	not used	4	4
Milk consumption from livestock[b]	L/yr	not used	not used	not used	92
Meat consumption from livestock[b]	kg/yr	not used	not used	not used	63
Fish consumption[b]	kg/yr	not used	not used	not used	5.4
Other seafood consumption[b]	kg/yr	not used	not used	not used	not used
Drinking water intake[f]	L/yr	not used	not used	not used	700
Fraction of drinking water from on-site well[b]	-[c]	not used	not used	not used	1
Fraction of aquatic food from on-site pond[b]	-[c]	not used	not used	not used	0.5
Livestock fodder intake for meat[b]	kg/d	not used	not used	not used	68
Livestock fodder intake for milk[b]	kg/d	not used	not used	not used	55
Livestock water intake for meat[b]	L/d	not used	not used	not used	50
Livestock water intake for milk[b]	L/d	not used	not used	not used	160
Mass loading for foliar deposition[b]	g/m^3	not used	not used	0.0001	0.0001
Depth of soil mixing layer[b]	m	0.15	0.15	0.15	0.15
Depth of roots[b]	m	not used	not used	0.9	0.9
Contaminated fraction					
Drinking water[b]	-[c]	not used	not used	0	1
Household water[b]	-[c]	not used	not used	0	1
Livestock water[b]	-[c]	not used	not used	not used	1
Irrigation water[b]	-[c]	not used	not used	not used	1
Produce[b]	-[c]	not used	not used	not used	1
Meat[b]	-[c]	not used	not used	not used	-1
Milk[b]	-[c]	not used	not used	not used	-1

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TABLE A.1 (Cont.)

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Groundwater fractional usage (balance from surface water)					
Drinking water[b]	-[c]	not used	not used	not used	1
Household water[b]	-[c]	not used	not used	not used	1
Livestock water[b]	-[c]	not used	not used	not used	1
Irrigation[b]	-[c]	not used	not used	not used	1
Total porosity of the house or building[b]	-[c]	0.1	not used	0.1	0.1
Volumetric water content of cover material[b]	-[c]	not used	not used	not used	not used
Volumetric water content of the foundation[b]	-[c]	0.05	not used	0.05	0.05
Diffusion coefficient for radon gas	m^2/s				
in cover material		not used	not used	not used	not used
in foundation material[b,f]		2.0×10^{-6}	not used	2.0×10^{-6}	2.0×10^{-6}
in contaminated zone material[b,f]		2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}
Emanating power of radon gas[b,f]	-[c]	0.2	0.2	0.2	0.2
Radon vertical dimension of mixing[b]	m	2.0	2.0	2.0	2.0
Average annual wind speed[a]	m/s	5.3	5.3	5.3	5.3
Average building air exchange rate[b,f]	hr^{-1}	1.0	not used	1.0	1.0
Height of the building (room)[b]	m	2.5	not used	2.5	2.5
Bulk density of building foundation[b]	g/cm^3	2.4	not used	2.4	2.4
Thickness of building foundation[b]	m	0.15	not used	0.15	0.15
Building depth below ground surface[b]	m	1.0	not used	1.0	1.0

[a] Values based on site specifications as documented by DOE (1992, 1993a, and 1994).

[b] Values based on scenario assumptions or default parameter value.

[c] Parameter is dimensionless.

[d] Distribution coefficient values for uranium are based on laboratory analyses of site specific soil samples from the Wayne site (DOE 1993b); values for radioactive decay products are based on published values for similar soil types (Baes et al. 1984; Sheppard and Thibault 1990).

[e] Radionuclide is a decay product.

[f] Values based on scenario assumptions specified by DOE (1993a).

[g] Mass loading for inhalation assumes that the total mass loading of airborne particulates is 200 μg/m³, that 50% of the airborne particulates originated from soil or soil-like material, and that 30% of the airborne particulates are of respirable size (DOE 1993a).

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APPENDIX REFERENCES

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(2) Selection and use of respirators to protect employees against hazards to which they may be exposed.

(3) Nature and extent of the respiratory hazards to which the employees may be exposed.

(4) Structure and operation of the entire respirator program. Supervision shall understand his/her responsibility to facilitate functioning of the program, including maintenance that the employees may be able to do themselves, issuance of respirators, control of their use, and evaluation of the program's effectiveness.

(5) The legal requirements pertinent to the use of respirators.

NOTE: Most respirator manufacturers have established respirator training programs that are available to buyers of their respirators. These programs should be reviewed to determine if they are applicable to the respirators presently being used on the jobsite.

.12 Fit Testing (Qualitative)

Employees must be allowed to test the facepiece for face seal of the respirator and wear it in a test atmosphere.

METHOD OF TESTING

(1) Test 1 - Negative Pressure Test

This test consists of merely closing off the inlets of the canister, cartridge(s) or filter(s' by covering with the palm(s) or replacing the seals over the canister or cartridge inlets, or by squeezing breathing tubes so that air cannot pass; inhaling gently so the facepiece collapses slightly, and holding the breath for ten seconds. If the facepiece remains slightly collapsed and no inward leakage is detected, the respirator is probably tight enough. This test, of course, can only be used on respirators with tightly fitting facepieces. This test shall only be used as a very gross determination of fit.